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Distribution of total non-structural carbohydrates in soybean plants at stages of development[1]

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Abstract : Five varieties of soybeans were grown in the summer of 1979 and in the spring of 1980. Concentrations of total non-structural carbohydrates (TNC) were determined in different plant fractions harvested at intervals of development. Leaf blade TNC was consistently higher in the spring than in the summer crop, presumably the results of environmental influences. Rapid decline in leaf TNC during pod-filling and the low concentrations (2-3%) in the abscised leaves suggested the redistribution of assimilates. Stems, petioles and pod walls were also sites of stored carbohydrates to meet the demands of developing seeds. In some cases, the presence of abundant TNC in pod walls at R4 stage, along with the decrease of TNC in vegetative organs implied possible requirement of stored energy for the differentiation and growth of pod walls. Translocation from pod walls to seeds was more conspicuous in late (R6-R8) than in early (R4-R6) seed-filling period. Changes of root and nodule TNC were correlated with those of dinitrogen-fixing activity as previously reported. Compared with other varieties, Shih-Shih and Kaohsiung No. 3 maintained relatively high TNC concentrations in roots and nodules during the reproductive phase which coincided with higher activities of dinitrogen fixation. The early-maturing Shih-Shih was characterized by high TNC levels in leaf blades and stems, especially in the spring crop season.

The importance of total non-structural carbohydrates (TNC) to the physiology and yield performance of soybean plants has received less attention than that of nitogen, due mainly to the relatively low carbohydrate concentration in the seeds. However, carbohydrates are the main energy source for the growth and development of almost all the crops. Besides, they are the main substances translocated from maternal tissues to the seeds during pod-filling period of soybeans and are the raw materials for protein and lipid synthesis [8,11,15]. Lawn and Brun [10] reported the close relationship between photosynthate distribution and symbiotic N_2 fixation. Unlike maize, rice, and barley, the soybean stems do not act as temporary storage sites for seed-bound carbohydrates [8]. Thorne [17], on

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the other hand, observed the redistribution of carbohydrates from pod-walls in short-season soybean varieties. The "nearest-source" concept was further demonstrated by Streeter and Jeffers [16] by indicating the possible contribution of stored carbohydrates in the stems and petioles to the grain yield of soybean crops.

Recent studies [12,16] suggested that soybean plants may be capable, from the standpoint of TNC but not N content, of supporting a greater reproductive load than is usually maintained to maturity. It is therefore of interest to understand the role that carbohydrates, as well as N, play in affecting the physiological activities and yield potential of soybeans.

We have reported the nitrogen status and its relation to N_2 fixation and leaf physiological activities of developing soybean plants [7]. As no information in carbohydrate distribution is available on local varieties grown in Taiwan, the study herein was conducted to investigate the changing patterns of TNC in different plant fractions during the development of early- and medium-maturing soybean varieties. Assessment was also made on their possible impact upon the potential of grain yield.

Materials and Methods

Five commercial soybean varieties, Shih-Shih, Tainung No. 4, Wakasima, Palmetto, and Kaohsiung No. 3, were grown in the summer crop season (July-October) of 1979 and the spring crop season (February-May) of 1980 in 3×4.5m plots with 5 replications. Planting density was 50×10 cm. Stands were thinned to two plants per hill after emergence. N, P, and K at the rate of 24, 54, and 96 kg/ha, respectively, were applied at the time of sowing. Experiment was conducted in the experimental farm of Taiwan Agricultural Research Institute, Wufeng, Taichung, Taiwan.

Samplings were made at V3, V5, V7, R2, R4, R6, and R8 stages of plant development according to Fehr *et al.* [6] for determining the concentration of total non-structural carbohydrates. Whole plants including roots with soils were taken from field to the laboratory, cleaned with tap water and dried with towels. They were then separated into leaf blade, petiole, stem, pod wall, root, and nodule fractions. Samples were dried in an air-drafted oven for 2 hrs at 100°C followed by 80°C for 46 hrs, and ground in a Wiley mill through a 40-mesh screen.

Concentration of total non-structural carbohydrates was analyzed according to Smith [14]. Ground samples were first hydrolyzed with takadiastase ("Clarase 40,000", courtesy of Miles Laboratories Inc., U. S. A.) at 40°C for 44 hrs, and reducing sugars were measured by the Shaeffer-Somogyi copperiodometric titration method described by Heinze and of Murneek [cf. 14]. This method of hydrolysis for the determination of TNC has been demonstrated by Streeter and Jeffers [16] and tested by this laboratary as most acceptable for precision, accuracy and recovery of standard added to samples.

Results

Table 1 compared the concentrations of total non-structural carbohydrates in leaf blades of various at stages of development. For the summer crop of 1979, TNC concen-

trations ranged between 2.50-10.36% during the period of V3 to R6. The levels were much higher (3.29-20.78%) for the spring crop of 1980.

Leaf TNC decreased from V3 to V5 and reached the peak value at V7 stage for the soybeans grown in the summer. Shih-Shih, an early-maturing variety, maintained high and constant TNC levels in the leaf blades between V7 and R4 (9.64-9.92%) whereas the other four varieties showed sharp declines during this period, e. g., 2.75-4.25% at R2 and 2.50-3.47% at R4 stage. Generally, TNC concentrations increased slightly from R4 to R6 and decreased again towards maturity. Concentrations at harvest were below 3% except Shih-Shih which still possessed 5.37% of its leaf dry weight as available carbohydrates (Table 1).

Table 1. TNC concentrations (%, dry basis) in leaf blades of developing soybean plants grown in the summer (1979) and spring (1980) crop seasopn

Variety	Crop Season	Developmental Stage						
		V3	V5	V7	R2	R4	R6	R8
Wakasima	Summer	8.09	4.13	9.27	3.10	2.50	3.42	1.91
	Spring	4.13	10.18	16.26	12.69	12.28	11.24	3.54
Tainung No. 4	Summer	8.62	4.00	10.36	2.75	3.47	5.37	2.55
	Spring	4.50	11.75	10.82	11.28	12.49	5.07	2.17
Shih-Shih	Summer	7.93	6.01	9.64	9.92	9.67	7.26	5.37
	Spring	10.69	12.60	15.51	16.56	20.78	8.61	5.51
Kaohsiung No. 3	Summer	8.81	4.12	9.68	4.25	2.61	8.39	2.64
	Spring	3.29	9.58	15.46	10.24	11.85	6.30	2.61
Palmetto	Summer	8.60	6.21	7.15	3.34	3.16	4.98	2.86
	Spring	10.07	9.98	11.46	8.55	9.50	7.09	2.25

A different pattern of changing TNC status was observed in the spring crop. Levels of TNC increased continuously from V3 to V7 and remained high until R4 stage. Concentrations at R4 were between 10-20% for most varieties which were well above the values of summer crop (2.50-9.67%) at comparative growth stage. Highest concentration of 20.78% was also recorded in Shih-Shih variety. The values then decreased rapidly during the pod-filling period (R4-R8) and were below 3% at maturity with the exceptions of 3.54% for Palmetto and 5.51% for Shih-Shih. In other words, TNC concentrations in abscised leaves were similar between the two crops despite the obvious seasonal difference in TNC changes throughout most of the growing period.

The changing pattern of TNC concentrations in leaf petiole (Table 2) was similar to that in leaf blades. In the summer crop season, there were no significant differences

at V3 stage among the 5 tested varieties (5.01-5.81%). TNC levels reached the maximum at V7 (6.10-10.56%) and declined markedly between R6-R8 stages. It was noted that petiole TNC of Shih-Shih remained fairly constant (8.08-9.02%) from V7 to R6 developmental stages while those for the other varieties showed fluctuations during the same period. Concentrations at harvest were between 1.24-2.23% which were lower than those in the leaf blades. For the spring crop of 1980, petiole TNC increased linearly from V3 to V7 and changed little thereafter until R4 stage. The concentrations were much higher than those of the summer crop, especially during the late vegetative and early reproductive periods (V7-R4), e. g., 13-16% vs. 8-9% for Shih-Shih and 16-18% vs. 6-11% for Wakasima (Table 2). TNC decreased considerably then from R4 to maturity and was only 1.39-1.84% at the time of harvest. Comparisons among varieties showed that unlike leaf blades, petioles of the early-maturing Shih-Shih were not higher in TNC than those of the other varieties.

Table 2. TNC concentrations (%, dry basis) in leaf petioles of developing soybean plants grown in the summer (1979) and spring (1980) crop seasons

Variety	Crop Season	Developmental Stage						
		V3	V5	V7	R2	R4	R6	R8
Wakasima	Summer	5.01	5.11	10.56	6.32	6.08	3.66	1.24
	Spring	3.97	6.57	17.66	16.51	16.81	7.16	1.42
Tainung No. 4	Summer	5.06	3.57	9.62	5.05	8.70	11.63	2.23
	Spring	3.86	6.80	12.36	10.63	12.74	9.52	1.84
Shih-Shih	Summer	5.21	5.92	8.08	8.62	9.02	8.11	1.81
	Spring	5.12	8.31	13.49	15.04	15.85	8.92	1.39
Kaohsiung No. 3	Summer	5.81	5.59	8.78	3.64	5.12	8.95	1.40
	Spring	3.84	6.74	14.81	9.03	10.46	6.42	1.40
Palmetto	Summer	5.71	2.94	6.10	5.52	6.00	4.76	2.21
	Spring	4.26	6.35	9.10	9.30	9.92	4.37	1.62

TNC concentrations in the stems were shown in Table 3. Except Shih-Shih, Kaohsiung No. 3 and Palmetto in the summer crop and Palmetto in the Spring crop, the others showed the highest TNC concentration in the stems at V7 stage. The decline after V7 was followed by an increase from R4 to R6 for most varieties in the summer crop season. The most significant decreases were observed between, in addition to V7-R2, R6 and R8 stages (from 4-6% to 1-1.5%). A different picture was noted in the spring season. Stems of Wakasima, Shih-Shih, and Kaohsiung No. 3 contained higher than 10% of available carbohydrates before stage R4. Sharp declines were observed at R6 and R8 sta-

ges. On the other hand, TNC concentrations in the stems of Tainung No. 4, a medium-maturing and high-yielding variety, decreased from 11.01% to 6.67% early in the reproductive phase (V7-R2). The level was not decreased further until full maturity. For Palmetto, a continuous decline after V7 was characteristic. Concentration of TNC in the harvested stems ranged from 1-1.5% which were somewhat lower than those in the leaf blades and petioles (Table 3).

Table 3. TNC concentrations (%, dry basis) in stems of developing soybean plants grown in the summer (1979) and spring (1980) crop seasons

Variety	Crop Season	Developmental Stage						
		V3	V5	V7	R2	R4	R6	R8
Wakasima	Summer	3.95	5.94	7.62	3.59	3.69	4.14	1.49
	Spring	4.61	8.40	13.10	9.89	11.49	5.20	1.30
Tainung No. 4	Summer	5.71	3.32	6.29	4.03	3.56	6.28	1.00
	Spring	4.41	7.90	11.01	6.67	6.87	5.92	1.42
Shih-Shih	Summer	7.68	4.91	5.10	5.99	5.59	6.02	1.48
	Spring	12.36	11.62	12.53	11.46	12.23	5.61	1.42
Kaohsiung No. 3	Summer	6.18	4.99	5.28	3.71	4.39	5.91	1.43
	Spring	6.07	8.91	12.44	6.40	10.77	3.51	1.22
Palmetto	Summer	6.35	2.35	4.38	3.65	3.84	3.48	1.33
	Spring	12.19	7.31	7.70	5.43	4.40	3.87	1.10

The roots of soybeans contained less TNC when compared with other plant fractions (Table 4). The concentrations were generally below 5% for all the varieties at any developmental period. Highest values were also recorded at V7 stage in both crops except Shih-Shih, and a second peak occurred at R4 or R6 depending on varieties or crop seasons. When grown as summer crop, Kaohsiung No. 3 had relatively high TNC content in the roots at R6 (4.74%) followed by Shih-Shih (3.27%). The concentration for other varieties ranged from 1.62% to 2.85%. Decreases in root TNC during pod-filling were more pronounced between R6 and R8 for the summer crop and between R4 and R6 for the spring crop. Table 4 also showed that final concentrations were usually below 1%.

Root nodules, the site of N_2 fixation, contained TNC at levels comparable to those in the roots in the summer crop. As shown in Table 5, maximum concentrations of 3.33-4.36% were reached at V7 stage except Shih-Shih which had the highest value (4.11%) at R2. In general, TNC decreased during the reproductive growth period. It was interest to note that Kaohsiung No. 3 and Shih-Shih were higher in TNC than the other varieties

Table 4. TNC concentrations (%, dry basis) in roots of developing soybean plants grown in the summer (1979) and spring (1980) crop seasons

Variety	Crop Season	Developmental Stage						
		V3	V5	V7	R2	R4	R6	R8
Wakasima	Summer	—	2.17	4.05	2.18	2.48	1.62	1.03
	Spring	3.30	4.08	5.05	4.43	5.72	1.91	0.86
Tainung No. 4	Summer		2.60	3.15	2.23	2.20	2.85	0.98
	Spring	2.64	2.93	3.73	2.72	3.13	2.10	1.03
Shih-Shih	Summer		1.84	2.31	2.79	3.09	3.27	0.77
	Spring	4.29	3.71	3.74	4.66	5.43	2.16	0.92
Kaohsiung No. 3	Summer		2.63	4.22	3.77	2.75	4.74	0.61
	Spring	3.15	3.32	4.89	3.42	4.10	2.03	0.86
Palmetto	Summer		2.53	2.59	2.61	2.09	2.04	1.16
	Spring	3.96	3.24	3.12	2.06	2.23	1.54	1.26

Table 5. TNC concentrations (%, dry basis) in root nodules of developing soybean plants grown in the summer (1979) spring (1980) crop seasons

Variety	Crop Season	Developmental Stage				
		V5	V7	R2	R4	R6
Wakasima	Summer	3.23	4.36	3.21	2.15	1.38
	Spring	14.58	11.86	4.30	4.40	2.70
Tainung No. 4	Summer	3.31	3.33	2.62	2.12	1.92
	Spring	10.60	6.03	4.60	3.85	2.98
Shih-Shih	Summer	2.49	3.33	4.11	2.91	2.38
	Spring	14.69	9.65	6.13	5.46	2.77
Kaohsiung No. 3	Summer	2.92	3.66	2.37	2.45	3.14
	Spring	14.44	11.51	4.93	6.17	2.86
Palmetto	Summer	2.53	3.71	2.31	1.99	1.42
	Spring	16.81	8.83	4.93	5.73	2.65

during the developmental period of R2 to R6. At R6, or rapid pod-filling, when the activity of N_2 fixation showed marked decline, nodule TNC was between 1.38-1.92% for Wakasima, Tainung No. 4 and Palmetto. They were 2.38% and 3.14%, respectively, for Shih-Shih and Kaohsiung No. 3.

For the spring-grown soybeans, maximum TNC concentrations of 10.60-16.81% in root nodules recorded occurred at V5 stage (Table 5). Those values were 3 to 4 times higher than the highest concentrations (3.33-4.36% at V7) in the summer soybeans. TNC decreased continuously from V5 with the advance of maturity. They ranged between 4-6% during the period of pod development (R2-R4), which were also higher than those (2-4%) of the summer crop. Shih-Shih and Kaohsiung No. 3 contained more TNC in root nodules than the other varieties in this period. However, no varietal difference was found at R6 stage.

Table 6. TNC concentrations (%, dry basis) in pod walls of developing soybean plants grown in the summer (1979) and spring (1980) crop seasons

Variety	Crop Season	Developmental Stage		
		R4	R6	R8
Wakasima	Summer	7.70	4.20	2.86
	Spring	6.46	8.56	2.95
Tainung No. 4	Summer	6.90	5.73	3.31
	Spring	6.50	7.07	2.71
Shih-Shih	Summer	7.30	4.96	2.68
	Spring	6.76	6.08	2.75
Kaohsiung No. 3	Summer	5.31	6.80	2.72
	Spring	7.87	6.58	2.32
Palmetto	Summer	6.81	5.88	3.25
	Spring	8.05	6.37	2.39

Table 6 showed the concentrations of TNC in pod walls during the reproductive phase of R4 to R8. Pod-wall TNC peaked at R6 for Kaohsiung No. 3 (6.80%) while the maximum concentrations were recorded at R4 for the remaining varieties (6.81-7.70%) in the summer crop. On the other hand, Wakasima and Tainung No. 4 showed increases from R4 to R6, whereas Shih-Shih, Kaohsiung No. 3 and Palmetto were highest in TNC at R4 stage in the spring crop season. Decreases during this period of pod-filling were more significant between R6 to R8 stage in most cases. Final concentrations of TNC in the abscised pod walls, ranged from 2.32 to 3.31%, did not suggest any seasonal or varietal difference.

Discussion

Leaf blade TNC was significantly higher in the spring than in the summer crop (Table 1), presumably the result of environmental difference. Pattern of temperature-change during the course of soybean development is from low to high in the spring and from high to low in the summer crop season. According to the climatic study of Chen and Chen [1], at the time of reproductive growth, soybeans grown as spring crop (April -May) were under higher temperature and solar radiation than as summer crop (Sept. -Oct.). Consequently, levels of TNC in leaf blades of the former 2-5 times higher than those of the latter.

Dunphy and Hanway [3] reported that water-soluble carbohydrate concentration in the leaves increased during the growing season and reached 15-17% when the leaves started to yellow (R7). Ciha and Brun [2], on the other hand, found little change in starch and free sugar levels during the seed filling period. The results of this experiment showed a slight increase in TNC concentration in the leaves from R4 to R6 stage in the summer crop but a sharp decline in the spring crop, indicating possible difference in assimilate distributiion and activities of assimilation between the two crop seasons.

The effect of carbohydrate concentration on photosynthesis has been a subject of interest and dispute. Thorne and Koller [18] found that starch concentration in soybean leaves was inversely correlated with the rates of net photosynthesis and assimilate translocation. They also observed that sucrose level had little adverse effect on the photosynthetic rate. In studying single-leaf photosynthesis during leaf expansion, Silvius *et al.* [13] did not find any correlation between starch concentration and synthetic activity and suggested that sucrose phosphate synthetase might have an important regulatory role in photosynthate partitioning and translocation. The results of this study did not provide direct evidences because starch and sucrose concentrations had not been determined separately. However, the marked differences in leaf TNC between crop seasons and among varieties did suggest possible variations in photosynthetic activities as the efficiency of leaves was judged by their capacity to export assimilate to centers of assimilate demands [13]

Dunphy and Hanway [3] pointed out that the continuous increase in leaf water-soluble carbohydrate concentration during the seed-filling period was a limiting factor for seed production. Streeter and Jeffers [16] found that increasing reproductive load by 30% appeared to have little effect on the levels of TNC and hence concluded that stored carbohydrates in leaf blades were relatively unavailable for supporting seed development. Similar results were obtained by Egli *et al.* [5] On the contrary, we found sharp declines in leaf blade TNC during late seed development (R6-R8) , especially for the spring (Table 1). Wilson *et al.* [20] showed that reduced pod set caused increased carbohydrate accumulation in the leaves of male-sterile soybean plants. These results implied that leaf blades were possible source of stored carbohydrates to the developing seeds. Table 1 also showed very low leaf TNC (2-3%) at R8 stage (maturity) in both crop seasons which was far below the results of Dunphy and Hanway [3] (15-17%), Streeter and Jeffers [16]

(9-10%), and Egli *et al.*[5] (8.5% starch plus free sugar) but was comparable to the values reported by Hsu [cf.3] (2-3%). Our results suggested the existence of extensive translocation of leaf carbohydrates to the seeds in the spring crop as a result of either seed demands or leaf senescence. Variations in the source-sink ratio due to variety-environment interactions should also be considered in discussing the contribution of leaf carbohydrate to the grain yield of soybeans.

Concentrations of TNC were highest in the petioles (Table 2) and stems (Table 3) at the stage of V7 and declined rapidly during pod and seed development. Dunphy and Hanway[3] reported similar accumulation of water-soluble carbohydrates prior to seed filling and the subsequent decreases in these vegetative organs. Stephenson and Wilson[5] also reported that between pre-flowering and early pod development, assimilate was stored in the stems and transferred to pods during later development. Further evidence was provided by Kollman *et al.*[9] by indicating a 40% decrease in the amount of stem plus petiole carbohydrates was associated with increasing sink size from zero to 2.7 pods per node. It was thus clear that stems and petioles served as major sources of stored carbohydrates for the developing seeds, a conclusion also stated by Streeter and Jeffers[16]. Furthermore, the results of this study suggested that pod differentiation might also require the supply of stored energy from stems and petioles for at least some of the tested varieties. Its implication to grain yield or sink capacity remained to be clarified.

Pod walls were also able to provide carbohydrates accumulated earlier to the developing seeds. Table 6 showed the marked decline of TNC concentration in pod walls from R4 to R8 stages for all the tested varieties. Such translocation was more conspicuous between R6 to R8 for most varieties in both crop seasons, suggesting the dependence of seeds on stored carbohydrates during the rapid-filling period. Actually, TNC continued to accumulate in pod walls from R4 to R6 in some cases. Thorne[17] calculated that 12.7% of the final seed yield of Norman soybean was contributed by the redistributed carbohydrates from pod walls. In an earlier report, Egli *et al.*[4] also suggested that leaf blades and pod walls were the main sources of supplying nitrogen to the seeds.

The roots of soybean plants had TNC concentrations lower than other vegetative organs with the highest concentration not exceeding 6% at the stage of V7 or R4 (Table 4) which were in close agreement with previous reports in soybeans[11,16]. It was found that the size of reproductive load affected significantly root carbohydrate content. Wilson *et al.*[20] reported that total carbohydrates in roots of male-sterile soybean plants increased from 1.7 to 7.6 times that in the male-fertile roots. Using labelled CO_2 to study the distribution of assimilates in soybeans, Hume and Criswell[8] observed less translocation of ^{14}C-labelled materials to the roots in the reproductive stage than in the vegetative stage. The decline of root TNC during reproductive growth shown in this study might therefore indicate that carbohydrates were consumed locally rather than transported to other demanding sink.

Stephenson and Wilson[15] showed that leaves exported little carbohydrate to the

roots during pod-filling. Hume and Criswell [8] also found that root nodules harvested one week after $^{14}CO_2$ assimilation at flowering accumulated more ^{14}C than after $^{14}CO_2$ assimilation at other stages, indicating that assimilate supplies to nodules were greatest at flowering. Similarly, the activity of N_2-fixation was also highest during this period [7]. The importance of photosynthetic products to symbiotic N_2-fixation has been acknowledged for some time. Lawn and Brun [10] reported the decline of N_2-fixing activity in soybeans during pod-filling was the result of inadequate assimilate supply to the nodules. The pattern of decreasing nodule TNC, as shown in Table 5, was parallel to that of decreasing N_2-fixing activity reported by Lawn and Brun [10] and this laboratory [7]. Therefore, how to keep TNC in roots and nodules at higher levels in order to prolong the N_2-fixing activity is important in maintaining better N nutrition and physiological activities of the soybean plants.

The remarkable linearity of seed growth (unpublished data) in spite of daily fluctuation of photosynthate production [19] suggested a possible role of assimilate redistribution. Streeter and Jeffers [16] concluded that the nearest sources - pod walls, stems, and petioles - served as sources of providing carbohydrates to the developing seeds. Thorne [17] also found that in extremely short-season cultivars, assimilate storage and redistribution might effectively lengthen the period of pod-filling and thus contributed significantly to seed yield. Judging by the changes in TNC concentrations in different fractions during the growth course of soybeans, we found that leaf blades, petioles, stems, and pod walls were all possible sites of stored carbohydrates for future seed development. The balance of carbohydrate distribution between roots and other organs during reproductive growth was also of extreme importance when activity of N_2-fixation was concerned.

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大豆植株內非構造性碳水化合物之分布[1]

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摘 要

試驗以五個大豆品種爲材料，於民國68年夏作與69年春作栽培，在各生育階段測定不同器官內非構造性碳水化合物（TNC）濃度的變化。試驗結果發現春作大豆葉片之TNC濃度顯著較夏作大豆爲高，係環境因子影響之結果，莢果充實期間葉片TNC濃度大幅下降，成熟期之老化葉片內僅介於2—3%之間，品種與期作間表現一致，顯示有光合成物質再分佈之現象；莖、葉柄與莢果壁貯存之碳水化合物亦同爲供應種子發育需要之來源。部份品種營養器官TNC濃度在生殖生長初期有降低的趨勢，同時莢果壁的含量上升，顯示貯存性碳水化合物對莢果壁之分化與生長具有重要性。碳水化合物自莢果壁向種子之轉流，以充實後期（R6-R8）較高，而充實前期（R4-R6）較低。根與根瘤內TNC濃度經發現與固氮作用活性呈平行關係存在，十石與高雄三號品種在生殖生長期之TNC濃度較其他品種爲高，同時具有較旺盛的固氮作用活性。早熟品種十石之葉片與莖內含有較多量非構造性碳水化合物，尤以春作之生殖生長期更爲明顯，是否與產量穩定性有關，尙待繼續研究。

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